DESIGN
HYDRO-ELECTRIC PLANT ON BIG SALMON RIVER, IDAHO.

BY
A. M. NEWHOUSE
G. D. PETTIBONE
H. W. JONES

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Design of proposed
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PROPOSED HYDRO-ELECTRIC POWER PLANT

on

BIG SALMON RIVER, IDAHO.

A THESIS

PRESENTED BY

ARTHUR M. NEWHOUSE

GERRY D. PETTIBONE

HARVEY W. JONES

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

MAY 1911.

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PART ONE:-

HYDRAULIC FEATURES

PART TWO;-

ELECTRICAL FEATURES.

22763

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Part One.

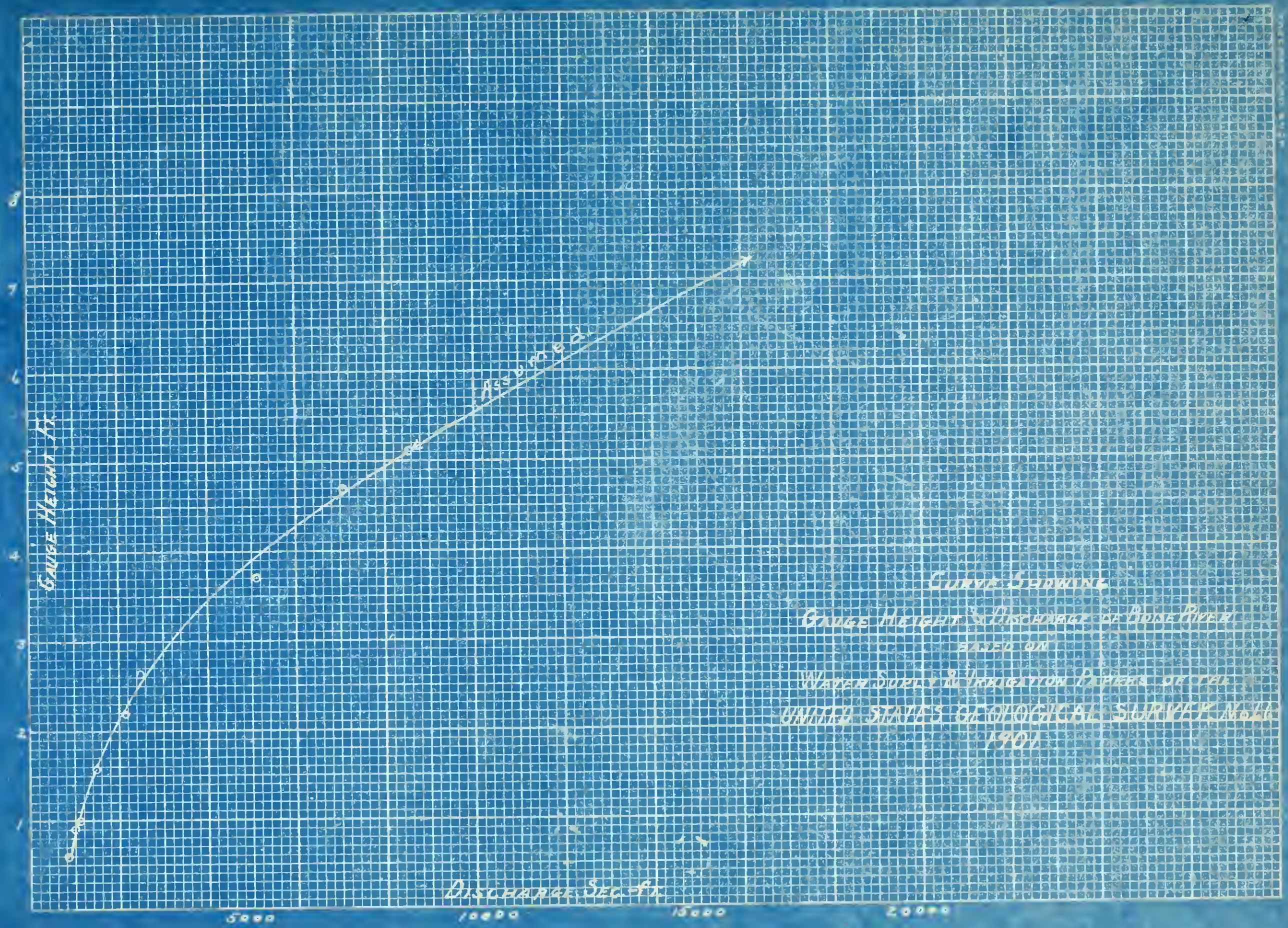
HYDRAULIC FEATURES.

STREAM FLOW DATA:- In the investigation to determine the stream flow, considerable difficulty was encountered owing to the fact that all public or government records contain little or no information regarding the Big Salmon River. The figures used, viz. 96,000 second feet for maximum discharge were obtained by a method of comparison, described below. The minimum of 5000 second feet was the figure obtained from investigations conducted in the vicinity of the proposed development.

The drainage basin of the Boise River adjoins that of the Big Salmon River, and for the former, the maximum recorded discharge gave a guage height of 7.2 feet, reported for May 16, 1901. These figures were obtained from "Water Supply and Irrigation Papers of the United States Geological Survey No. 66; Operations at River Stations 1901, Part 2, west of the Mississippi River."

According to the curve plotted and estimated from the rating table a guage height at Boise of 7.2 feet would mean a discharge of 16000 second feet. The estimated drainage area of the Boise River above Boise, Idaho, was estimated at 2000 square miles, hence, according to the above figures, the maximum discharge per square mile is 8 second feet.

The drainage area of the Big Salmon River was estimated at 12000 square miles and assuming the same discharge per square mile as was found for the Boise River, the discharge would be 96000 second feet for the Big Salmon River. The water supply papers show that the comparative precipitation of the Big Salmon and the Boise Rivers is in the ratio


Curve Showing
Gauge Height & Discharge of Boise River
Based on
Water Supply & Irrigation Papers of the
United States Geological Survey No. 16
1901

of 2.33:1.75, which would indicate that the maximum discharge for the former would be (2.33 x 96000) ÷ 1.75 - 128000 second feet. Owing to the lack of data for the Salmon River and the probability that the flow would not increase in direct proportion to the drainage area, 96000 second feet was used to design the spillway.

SLUICE GATES, RETAINING WALLS, and SPILLWAY SECTIONS: To take care of the discharge, it was necessary to provide both sluice gates and spillway, and figuring for the gates the formula $Q = NAC(2gh)^{.5}$ was used, where Q is the quantity discharged

n is the number of gates = 10

c is the coefficient = .8

g is the acceleration of gravity = 32.2

h is the head = 30 feet

.: $Q = 10 \times 100 \times .8 \times (2 \times 32.2 \times 30)^{.5} = 35000$ second feet.

Deducting this amount from the total discharge 96000 - 35000 = 61000 second feet to be discharged over spillway.

It was decided to build the dam 1500 feet in length, and as the gates and retaining section occupied 150 feet of length, it left for the spillway a length of 900 feet. To determine the head over the crest, the formula $Q = 3.33\,lh^{1.5}$ was used where

Q = quantity discharged

l = length of crest

h = head on crest

.: $61000 = 3.33 \times 900 \times h^{1.5}$ and solving for h = 7.5 feet D, the vertical depth of water over the crest of spillway

$7/8(h) = 6.5.$

The crest of spillway being at elevation 126.00, maximum flood water

will be at elevation 132.58.

Four foot flash boards are to be placed on crest of dam, which will raise normal water level to elevation 130.00. Ordinary high water conditions up to a maximum of 35000 second feet can be discharged thru 10 sluice gates placed in the dam and the elevation of water above dam kept approximately constant at elevation 130.00, normal elevation of tail race being 83 feet, that of head race being 47 feet.

The spillway section was designed for a head of 133 (high water) - 77.5 (elevation of river bed) = 54.5 feet. The height of the section was 48.5 feet. To determine the horizontal overturning moment, the formula $P = 1/2\ Wh(h+2d)$ was used, where P

$P =$ pressure

$W =$ weight of 1 cubic foot of water $= 62.5$

$h =$ height of section $= 48.5$

$d = 7/8\ h$, see above $= 6.58$

$\therefore P = 1/2(62.5 \times 48.5)\ (48.5+2 \times 6.58) = 94{,}211\#$

The vertical distance of the point of application of P above the base was determined by the use of the formula

$$p' = \frac{h + 3d}{h + 2d} \times \frac{h}{3}$$

$$\therefore p' = \frac{48.5 + 3 \times 6.58}{48.5 + 2 \times 6.58} \times \frac{48.5}{3} = 17.385 \text{ feet.}$$

The face of spillway is made up of the parabola, tangent and circle. The parabola was plotted according to the equation $x^2 = 1.98\ Hy$ and as $H = 6.58$, $x^2 = 13.03y$, or $y = x^2 \div 13.03$, giving the following coordinates:-

No.	x	y
1.	.077'	0' 15/16 "
2.	.306	3 11/16 "

No.	x	y
3.	.690	0' 8 1/4 "
4.	1.23	1' 2 3/4 "
5.	1.92	1' 10"
6.	2.76	2' 9 1/8 "
7.	3.16	3' 9 1/8"
8.	4.90	4' 10 13/16 "
9.	6.20	6' 2 3/8"
10.	7.67	7' 8 1/16 "
11.	9.25	9' 3"
12.	11.05	11' 5/8"
13.	13.00	13'
14.	14.98	14' 11 3/4 "
15.	17.20	17' 2 3/8 "
16.	19.60	19' 7 3/16 "

The area of the section was 1036.96 square feet.

The weight of the concrete is 150 lbs. per cubic foot.

.: the weight of one lineal foot of section was found to be 155,503 lbs.

In computing the pressures at the heel and toe of the section, the plane of maximum stress is perpendicular to the resultant of the horizontal water pressure and the vertical pressure due to the weight of the section. The unit pressure on the plane of maximum stress is found by dividing the resultant by the projection of the base on this line or $\frac{182000}{29.125} = 6.250$ lbs., and combining this unit stress with the flexural stress due to eccentricity.

In finding the stress in the concrete, the following equations were used:

$$M = \frac{SI}{c}\,; \quad M = Ve; \quad S = \frac{Mc}{I} = \frac{Vec}{I} \text{ and } I = \frac{bd^3}{12}$$

$\therefore S = 12\frac{Vec}{bd^3}$, where V = resultant pressure = 182000 lbs.

e = eccentricity of resultant = 4.834 ft.

c = 1/2 depth of section = 14.5625

d = depth of section = 29.125 ft.

b = breadth of section = 1 ft.

$$\therefore S = \frac{12 \times 182000 \times 4.834 \times 14.5625}{(29.125)^3} = 6223 \text{ lbs.}$$

Compression at toe = 6250 + 6223 = 12473 lbs.

" " heel = 6250 - 6223 = 27 lbs.

In designing the retaining section, volume moments were taken about the heel of the section and the center of gravity of the section found to be 19.39 feet from the up stream face of the wall.

The vertical pressure exerted by the weight of the wall and abutments was found in the same way as in the case of the spillway and amounted to 1560000 lbs. The uniform pressure on the plane of maximum stress was 8150 lbs. per square foot found in the same way as in the spillway problem. The maximum fiber stress, using formula

$S = \frac{12\,Vec}{bd^3} = 2605$ lbs.

Compression at toe = 8150 + 2605 = 10755#

Compression at heel = 8150 - 2605 = 5545#

Owing to the great pressure concentrated on the gates, when closed, it was necessary to put a girder in above the gate to strengthen the retaining wall, against which the top of the gate rested. Maximum high water conditions were provided for in the design.

Head at high water on center of gate = 35 feet.

Pressure on gate 10 x 10 x 62.5 x 35 = 218750.

It was assumed that one fourth of the pressure was distributed to

each side of gate, leaving the pressure to be carried by the girder equal to $\frac{218750}{4} = 54687.5$ lbs.

Figuring the bending moment from the formula

$M = 1/8\ Wl = 1/8 \times 54687.5 \times 10 \times 12 = 820{,}310$ inch lbs.

From Turneaure & Maurer "Reinforced Concrete", Page 60, formulas (3)' and (4)' $M_s = f_s A_s \times \frac{7d}{8}$ or $A_s = M_s / f_s \frac{7d}{8}$ where

d = depth of section (effective) = 31"

f_s = allowable unit stress in steel = 15000 lbs.

M = bending moment in inch lbs. = 820,310

A_s = area of steel

$\therefore A_s = \frac{820310}{15000 \times 27.125} = 2.02$ square inches

Checking for stress in concrete $M = f_c \times \frac{bd^2}{6}$ where

M = bending moment = 820310

b = breadth of section = 12"

d = depth of section (effective) = 31"

f_c = unit fiber stress in concrete

$\therefore f_c = \frac{6 \times 820310}{12(31)^2} = 427$ lbs. per sq. inch

which is well within the limit of safety.

Considering the water pressure on a foot width of the girder and proceeding by the above method, it was found that .69 square inches more steel were required, making a total of 2.71 square inches in the girder-- four 15/16" round rods being used.

The additional stress in the concrete due to the water pressure on the slab amounted to 146 lbs., bringing the total compression to 427 + 146 = 573 lbs. per square inch still within the allowable safe limit. The retaining wall itself was investigated by the above

method and f_c found to be 330 lbs. and A_s, 1 sq. in., the rods being spaced and placed as shown in accompanying drawings.

DESIGN OF CANAL- The character of the foundations and underlying strata in the vicinity of the proposed plant could not be accurately determined from any available records so it was assumed that there was rock below elevation 130 feet. The quantity of water flowing through the canal was 5000 cubic feet per second, the desired velocity four feet, giving required cross section area of 1250 square feet. The bottom width of canal at elevation105 was 50 feet side slopes in rock of 1 to 4 and above rock 2 to 1.

From Mead, Page 51, was gotten the following method of investigation for loss of head due to friction:

$$r = .353\ (A)^{.5} = .353\ (1250)^{.5} = 12.481$$

$$v = c\ (rs)^{.5} \quad .:\ s = v^2/c^2 r \text{ and } c = 96, .:\ s = 2.0016''$$

which is negligible. This however investigates for a rectangular cross section and the section of the canal was changed. The difference however in the result would be slight.

The intake to the canal through four submerged arches gave an entrance to the water at a velocity of about five feet. The arches were buttressed as shown on blue prints and designed to resist the maximum pressure of high water in case it ever becomes necessary to cut off the canal intake with stop logs. The stresses found were well within the limits of safety and amounted to 6088 lbs. at the heel and 8880 lbs. at the toe, both in compression.

INSTALLATION:- S. Morgan Smith, 42" quadruple turbines running at a velocity of 257 R. P. M. were used to operate each of the four units. They were set in open fore-bays in concrete vaults or chambers. Each unit capable of developing 5000 H.P. under a

47 foot head.

The exciter unit is to be driven by a James Leffel & Co. "Samson 17 C" wheel set on center line of power house and plant layout, in a concrete lined well supplied with water through a 36" intake from units number two and three on either side.

Part Two.

ELECTRIC FEATURES.

The next step in the design of a hydro-electric plant is the economical and conservative conversion of the available energy. Having given an amount of energy equivalent to twenty thousand horse power or about fifteen thousand kilowatts, it follows to decide upon the size and number of the units to be installed. There is no fixed rule regarding this matter so the engineer in charge must decide upon such machines as he thinks will do the required work. The units should not be too large, for if one should break down the others ought to carry the load without being excessively overloaded. Then, too, the larger the units the higher will be the efficiency. It is best to have the units of the same capacity. After due consideration it was decided to apportion the output of the plant to four alternators of thirty-seven hundred and fifty kilowatt capacity each, at unity power factor. These machines are of General Electric design, type ATB., having revolving fields. They generate at a voltage of sixty-six hundred and frequency of sixty cycles, are three phase and run at two hundred and fifty-seven revolutions per minute.

To obtain direct current for starting the plant and for reserve excitation as well as to furnish power to operate the oil switches, the crane, and to furnish lighting current for the building, it is proposed to install a seventy-five kilowatt water-driven direct current generator.

Each of the large generators carries on its shaft a thirty-seven and a half kilowatt direct current generator which furnishes the

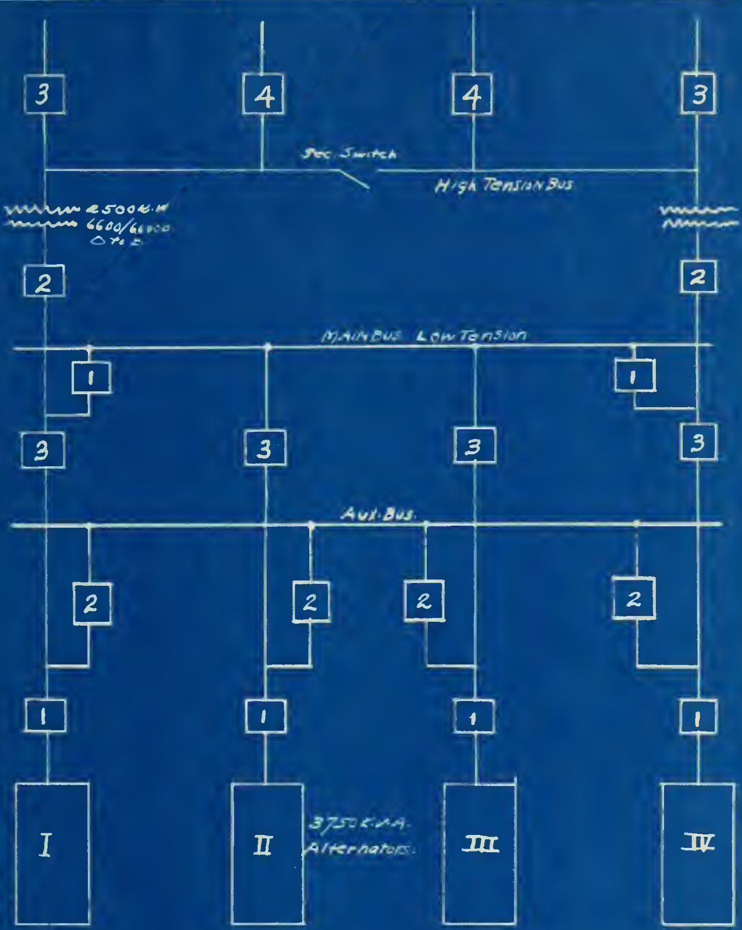
exciting current under normal conditions. Each generator has its own exciter, but the arrangement is such that the exciters may be paralleled with the seventy-five kilowatt machine in case such connection should be necessary.

Throughout the West it is common practice to transmit three-phase current at sixty cycles. The load is for the most part one of lighting, though, of course, some of it is for power. For power loads a low frequency of twenty-five cycles is better than sixty cycles, but the latter is used because it is best suited to power and lighting loads. Three-phase is adaptable for both lighting and power, particularly the latter. Then, too, three-phase transmission is the most saving in copper. The cost of copper is an important item in the cost of transmission.

It is proposed to erect two transmission lines each to be run in duplicate. These lines are to divide the load equally between an existing plant at Lewiston and a proposed plant at Oxbow Bend on the Snake River. These lines would be about sixty-five miles in length.

Remote control is used throughout the entire plant. The leads from the alternators run through conduit in the floor and the eighteen inch wall, which divides the generator from the transformer room, to potheads in the latter room. From the potheads, the three leads go to the current and potential transformers and to the lower terminals of the generator oil switches.

The switching room is behind the operating gallery on the second floor. All of the oil switches are located in this room. Theyare General Electric motor-operated, type H3, triple pole, double break switches.



Oil Switch Arrangement
for
Development of Proposed Hydro-Electric Plant
on
Big Salmon River, Idaho.

The leads run from the three generator switches to the generator busbars. These are located in a fourteen inch wall directly under the switches. From these busbars, which parallel all four generators, the leads are run through another oil switch to the low tension side of the transformers. The arrangement can be best understood by reference to the drawings and wiring diagram.

Two banks of transformers, one for each feeder, are to be used, with a reserve unit on rails. This transformer can be moved on the rails and used as a substitute for any one of the six others. The transformers are of the General Electric water-cooled type, of twenty-five hundred kilowatt capacity, single phase, sixty cycles and transform from sixty-six hundred volts to sixty-six thousand.

The transformers are connected delta to delta as this method of connection eliminates the third harmonic, and, in case of a breakdown in one transformer, the two others would carry the load on an open delta. If star connection were used a breakdown in one transformer would tie up the whole bank. However, the star connection has its advantage. The transformers do not have to be built for as high voltage as is the case with the delta connection.

The high tension sides of the transformers feed into high tension busbars which are sectionalized in the middle. These busbars are supported in the centers of compartments about four feet square, the latter being at the top of a wall twenty-four feet long and four feet wide. From the busbars the leads go to another set of type H3 oil switches. These are built for sixty-six thousand volts and tie the feeders on to the busbars. There are two of the oil switches for each feeder. Of the two for each feeder, one is on

the reserve line. The instrument transformers are located just under the gallery floor and intercept the high tension leads just before they go to the switches. From the feeder switches the leads go under the gallery floor, being separated by six inch barriers or walls, to the feeder compartment. This is simply a chamber ten feet wide and as high as the gallery. Then the leads are run vertically up to the choke coil and out through the wall insulator to the line.

In the upper part of the feeder compartment are supported the horn gaps for the General Electric electrolytic lightning arresters. These arresters are located on the groung floor in a compartment provided for that purpose. Connections to the horn gaps are made by cables which run up through the opening in the floor of the gallery.

The entire plant is controlled from a switchboard located in the gallery. It is a vertical board seventeen feet and four inches long and ninety inches high. It is to be constructed of white marble one and one-half inches thick with a one inch bevel. The board is made up of eleven panels, four twenty-four inches wide for generator control, two sixteen inches wide for feeder control, and five sixteen inches wide for exciter control.

The exciter panels are equipped as follows: one ammeter, one circuit breaker in the positive lead, one double pole single throw paralleling switch, one single pole single throw equalizer switch, one exciter field rheostat, and one potential plug. There is a direct current round type voltmeter on a bracket, which serves to indicate the voltage of any exciter or of the exciter busbars. The ammeters are of the horizontal edgewise type manufactured by the General Electric Company.

The four generator panels are equipped in the following manner: three ammeters, one for each phase, one indicating polyphase wattmeter and one power factor indicator, all of the horizontal edgewise type. There are, for controlling the motor operated oil switches, three small switches with bull's eye indicating lamps, and two switches for controlling the motor operated field rheostat and field switches. The handles of these switches when the motors are not in operation are in mid position. To have the motor revolve in one direction the handle is raised, to have it turn the other way the handle is lowered. The operating motors will continue to run as long as the handle is held in the up or the down position. The equipment of the generator panel also comprises a synchronizing receptacle, a potential plug, a polyphase integrating wattmeter, and two overload relays. These relays are for tripping the main generator oil switch. They are connected in series with the ammeters, current transformers, and current coils of the other instruments.

To conform with the rest of the board the feeder panels are equipped with horizontal edgewise ammeters of which there are three, four control switches for operating the oil switches, and two overload relays for tripping the feeder switches under abnormal conditions. There is also a polyphase integrating wattmeter.

In all cases the instruments are connected by transformers. The current transformers have a maximum value of five amperes flowing thru the secondaries. The potential transformers all step down to a secondary pressure of 110 volts. There are two current and two potential transformers the former being connected together on one side and grounded. The latter are connected open delta with the middle

point of the secondary grounded.

In order to provide a definite means of cutting out a crippled feeder, the two oil switches are electrically interlocked so that one must necessarily be open if the other is closed. The two generator switches which tie the machine on the main and auxiliary busbars are also interlocked so that the source of supply can be connected with but one busbar.

All of the control equipment for the excitation is located directly under the switchboard on the ground floor. There are the four motor operated type F General Electric generator field rheostats. On the vertical wall directly above the rheostats are mounted the solenoid operated field switches. As the leads leave the conduit they are taken one through the field switch to one busbar, and the other through the rheostat to the other busbar. The actual field circuit does not appear at the switchboard at all. The simple motor control circuit comes up to the generator panel.

The three leads from each exciter as well as from its field circuit are brought up to the respective panels on the board. The positive lead goes through one pole of the main switch, through the circuit breaker and down to the positive busbar. The negative lead goes to the other pole of the switch and to the negative bus. The equalizer lead goes to the equalizer switch and then to the equalizer bus. The three busbars are mounted on a pipe frame which is attached to the ceiling directly below the gallery floor under the control board. The busbars are of copper and designed for a current density of one thousand amperes per square inch.

In front of the control board the gallery floor extends out a

few feet enabling the operator to view the entire generator room. Under this projection on the ground floor is situated the house switch board. From this board the power for lighting the plant, for the machine and for the crane is controlled. Since the heaviest part of a generator weighs 53600# we will install a thirty ton traveling crane.

As much light as possible is obtained from the five foot windows along the back of the building and the twelve foot windows in the generator room. Provision is made for hauling new material into the plant. Thirty-five feet of track of standard guage is laid. The flat car can thus be run through the twelve foot door on to the track. Then the crane can pick up the material and carry it to any part of the generator room.

TRANSMISSION LINE.

Of prime importance in project of this kind, is, of course, the water supply or the amount of available energy. The next and very important feature is the transmission line. It can readily be appreciated that it is of vital importance to have the transmission line carefully worked out because upon it, to a large extent, depends the continuity of the service. In the design of a transmission line there are two features to be considered, the electrical and the mechanical conditions. They will be taken up in the order mentioned.

One of the first things to be considered is the kind of con ductors

to be used. There are several kinds in use but we will confine ourselves to two and decide upon on one of these. Copper and aluminum are the most common ones. Copper is the best known commercial conductor of electricity but due to the marked difference in weights the aluminum is coming into more general use right along. Aluminum weighs about one half what copper does so that freight charges may influence the choice of conducting material. The conductance of aluminum is only about 62 per cent of that of copper hence takes a larger cross section for a given current. The ultimate strength and elastic limit are quite comparable with those of copper so that from a mechanical standpoint aluminum can be used as well as copper. The coefficient of linear expansion is greater than that of copper so that higher towers have to be used to take care of the greater sag. Due to the necessary increase of cross section over that of copper the inductance is decreased while the capacity is increased. The aluminum forms an oxide on the surface of the conductor which tends to insulate it somewhat. Sleet and ice do not stay on it as readily as on copper, hence it is advantageous in that respect. After carefully considering these characteristics we decided to use a stranded aluminum cable.

Computations:-

Let

E=pressure between receiving wires in volts

W=power delivered in kilowatts

K=load power factor expressed as a decimal

A=cross section of conductor in millions of circular mils

W=total weight of conductor in pounds

l=length of circuit (each wire) in feet

R=resistance of each wire in ohms

t_1 =inductance factor of line equals ratio of line reactance to line resistance.

Q=per cent power loss in terms of delivered power.

P=per cent pressure drop in per cent of delivered pressure

$$F=\text{constant}=\frac{lw}{(kE)^2}$$

Spacing of conductors equal 72 in.

E=66000 volts

Frequency=60 cycles

W=7500 (assumed 8000kw)

k= .85 (assumed)

l=65 x 5280 = 343000 ft.

Q= 10%

$$F=\frac{343000 \times 8000}{(.85 \times 66000)^2} = .87$$

Percent pressure drop, $P= MQ+NQ^2$

where M and N are constants depending upon k and t_1 of circuit.

For aluminum conductor

$$A= \frac{1.67\ F}{Q} = \frac{1.67 \times .87}{10} = .145 \times 10^6 \text{ circ. mils}$$

Nearest commercial B & S guage is #000 with $A= .168 \times 10^6$ c. m.

$$\text{Exact power loss} = \frac{1.67 \times .87}{.168} = \underline{8.65\%}$$

From table

Reactance factor, $t_1 = 1.41$

$M = 1.354$, and $N= .0011$

Pressure drop, $P= 8.65 \times 1.354\ (.0011 \times (8.64)^2)$

$= 11.7+.0826 = 12.53\%$

The capacity susceptance of the line is b and equals $2\pi fC \times 10^{-6}$

where f is the frequency and C is the capacity in m.f.

From table

$$b = .00000091 \text{ for 1000 ft. and 100 cycles}$$

For this case

$$b = .00000091 \times .6 \times 1.03 \times 343 \times .62 = .0001195$$

Resistance = .0995 x 343 = 34.1 ohms

Therefore reactance, $Xt_1 = 1.41 \times 34.1 = 48.1$ ohms

Decrease in per cent pressure drop due to capacity effect = $P = 100bX$

$$= 100 \times .0001195 \times 48.1 = .575\%$$

Decrease in per cent power loss, q, due to capacity effect

$$q = 2at - \frac{a^2}{k^2 Q} \text{ where } a = 100bR \text{ and } t = .62$$

$$a = 100 \times .0001195 \times 34.1 = .407$$

$$\text{Therefore } q = 2 \times .407 \times .62 - \frac{(.407)^2}{(.85)^2 \times 8.65}$$

$$= .504 - .023 = .481\%$$

Hence the true pressure drop or % regulation

$$= 1253 - .575 = \underline{11.955\%}$$

True power loss = 8.65 - .481 = $\underline{8.169\%}$

Therefore generator pressure equals

$$66000(1 + .1195) = 73100 \text{ volts}$$

Charging current per wire equals

$$I = bE \times 1.15 = .0001195 \times 66000 \times 1.555 = \underline{9.14 \text{ amperes}}$$

MECHANICAL CONSIDERATIONS.

Let S_1 = span in feet

D = sag in feet

D_1 = vertical component of sag

W = weight of conductor plus weight of ice in lbs. per foot

W_0 = " " " only

W_r = resultant of W and wind pressure in lbs. per foot

T = maximum allowable tension in conductor

t = temperature in degrees Fahrenheit above the minimum (-40°)

k = temperature coefficient of linear expansion per degree

A = cross section in square inches

E_1 = stretching modulus of elasticity in lbs./in.^2

L_s = length in feet of single span of strung cable at minimum temperature

L_u = length in feet of unstressed single span of cable at minimum temperature

$$L_s = S_1 + \frac{S_1^3 W_r^2}{24 T^2}$$

$$L_u = \frac{L_s}{1 + \frac{T}{AE}}$$

$$D^3 = \frac{3 S_1}{8} (L_u(1 + kt) - S_1) D = \frac{3 S_1 L_u W_r}{64 A E_1}$$

$$D_1 = \frac{D W}{W_r}$$

For this case

diameter of conductor = .47 in.

$S_1 = 600$

D = ?

$W_o = \frac{816}{5280} = .1545$ lbs/ft

W_r = ?

A = .1317 sq. in.

T = 1850 lbs.

$t = 150^\circ$ F

k = .0000128

$E_1 = 9000000$

Weight of ice $= 57$ lbs/ft^3

Therefore weight of ice 1/2 in. thick per foot

$$= \frac{12x \left(\frac{1.97}{2}\right)^2 - \left(\frac{.47}{2}\right)^2}{1728} \times 57 = \frac{37.7\,(.54 - .055)}{1728} \times 57 =$$

.604 lbs/ft

Therefore $W = .1545 + .604 = .76$ lbs/ft.

Wind pressure $= \frac{1.47 \times 12}{144} \times 15 = 1.84$ lbs/ft

$$W_r = (\overline{.76}^2 + \overline{1.84}^2)^{.5} = 2 \text{ lbs/ft.}$$

Therefore $L_s = \frac{600 + (600)^2 \times (2)^2}{24 \times (1850)^2} = 600 + \frac{216000000}{82100000} = 602.63$

Therefore $L_u = \dfrac{60263}{1 + \dfrac{1850}{9000000 \times .1317}} = 601.98$

$t = 150^{\circ}F$

$$D^3 - \frac{3 \times 600}{8}\,(601.98(1.00992) - 600)D = \frac{3 \times 600^3 \times 601.98 \times 2}{64 \times 9000000 \times .1317}$$

$D^3 - 1350\,D = 10200$

$D = 40.1$

Vertical sag $= \frac{40.1 \times .76}{2} = 15.25$ ft.

Lowest point $= 15.25 + 25 = 40.25$ ft.

Weight of conductor plus ice $= 6 \times 600 \times .76 = 2740$ lbs.

Wind on conductor $= 6 \times 1.84 \times 600 = 6630$ lbs.

Wind pressure on 25 sq. ft. tower $= 25 \times 15 = 375$ lbs.

Assume 1/2 at top or 190 lbs.

Assume weight of tower $= 2000$ lbs.

Therefore the tower must withstand a weight of ice covered conductor and its own weight of 2740 plus 2000 = 4740 lbs.

and wind pressure on conductors plus wind on tower or

$$6630 + 190 = 6820 \text{ lbs. at top}$$

With the span of 600 ft., the required number of towers

$$N = \frac{343000}{600} = 572$$

The insulators are to be of the suspension type manufactured by the R. Thomas Co. Three units are to be hung in series to constitute one insulator. Hence for supporting six lines on each tower, the total number of insulators

$$N = 572 \times 6 = 3432$$

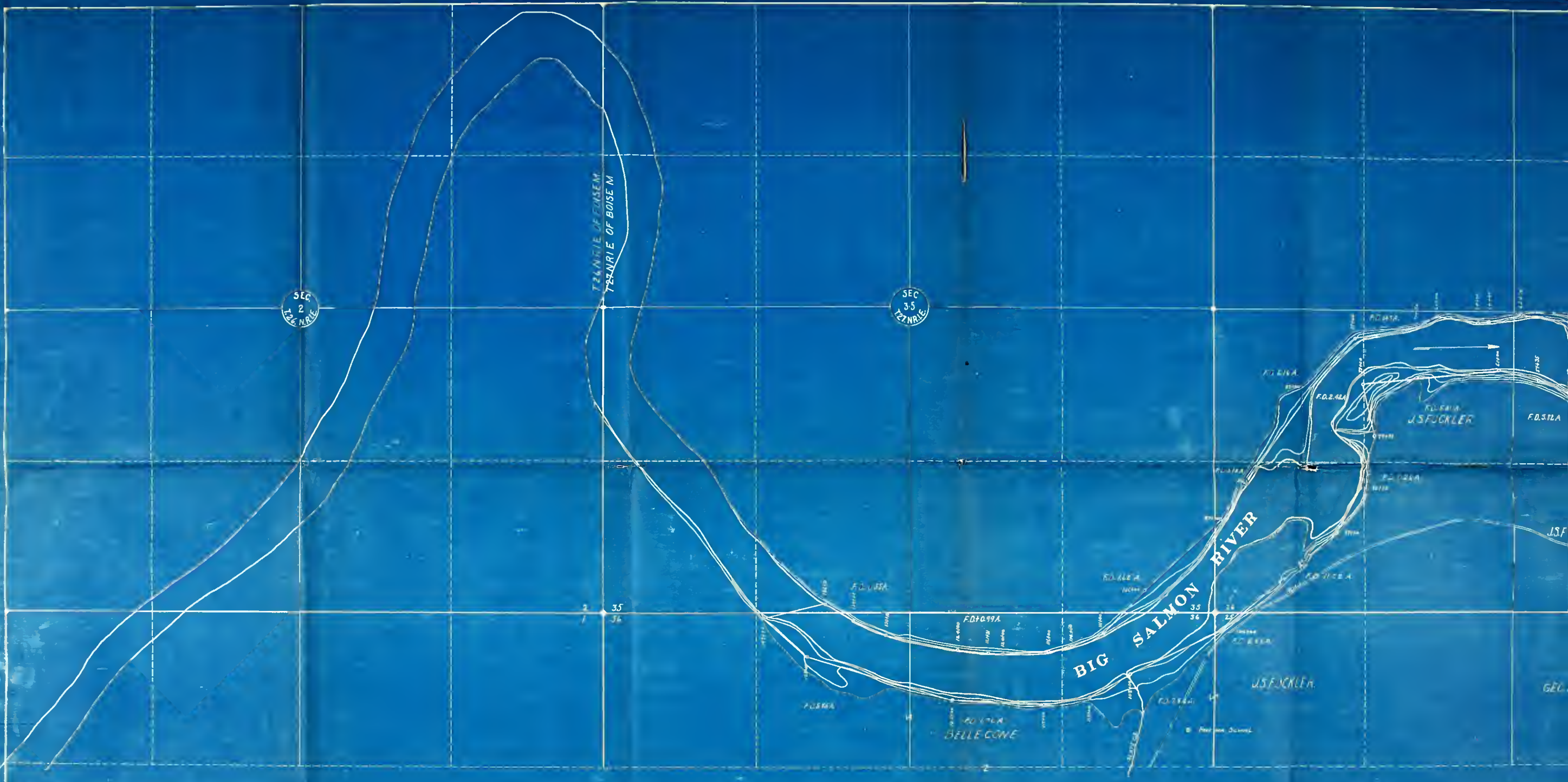
The total number of units equals

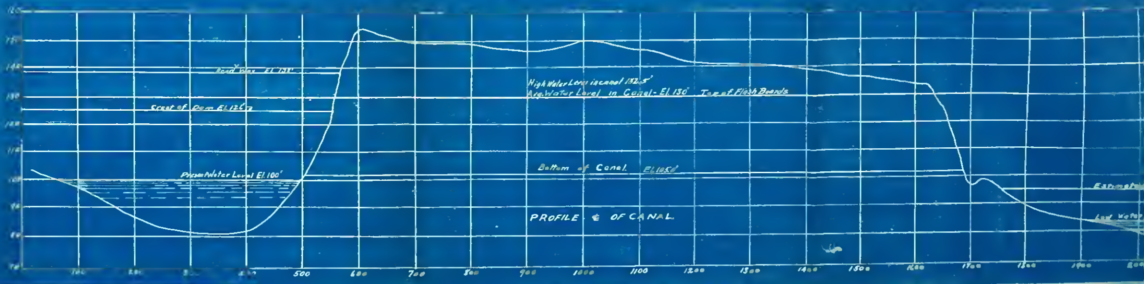
$$3432 \times 3 = 10296$$

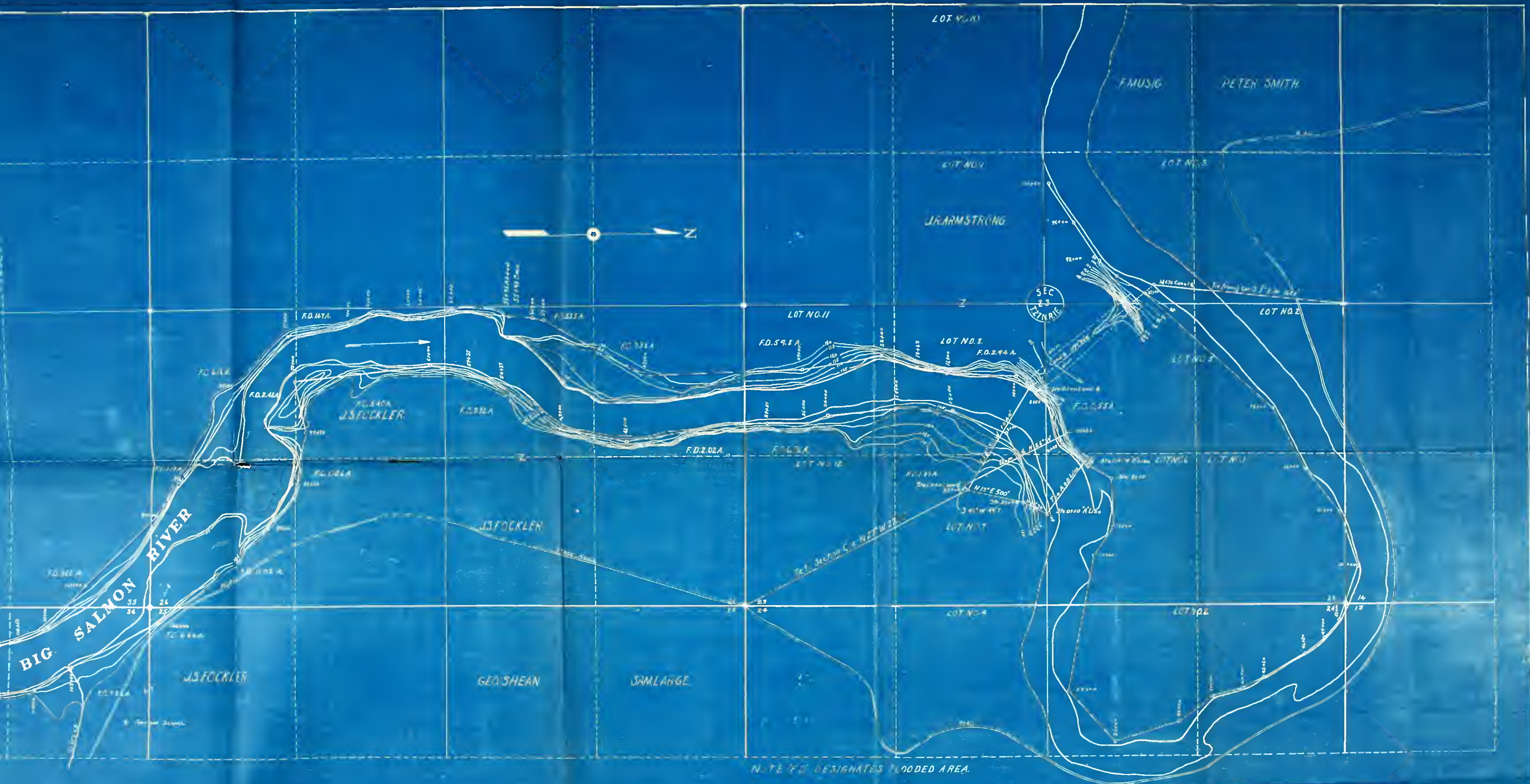
LIST OF DRAWINGS.

1. General Plan.
2. General Plan of hydraulic layout.
3. Plan of power house Superstructure showing electrical and hydraulic machinery.
4. Elevation of power house Superstructure showing eledtrical and hydraulic machinery.
5. Wiring Diagram of power house.
6. Control Board of power house.
7. Transmission Tower and Insulators.
8. Cross-section of Dam thru spillway and sluice gates.
9. Plan, Elevation, and Section of Intake Arches.
10. Plan and Elevation of Dam Sluice Gates.
    Detail of Operating Stand
    Cross-section of Forebay.
11. Plan of Forebay and power house Substructure.

LOT NO.10
MAP SHOWING LOC
①
C
O
ies.

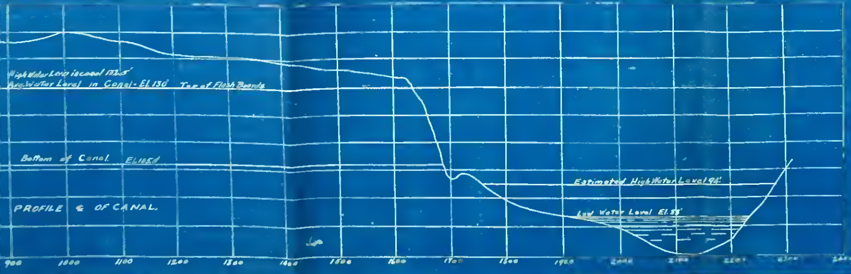

SEC 2 T.26 N.R.1E.
SEC 35 T.27N.R.1E.
T.26N.R.1E OF B.M.
T.27N.R.1E OF BOISE M
2
35
1
36
F.D.1.55A.
F.D.+0.99A.
F.D.2.42A
F.D.3.12A
35
36
36
25
BIG SALMON RIVER
J.S.FICKLER
J.S.FICKLER
BELLE CONE
J.S.F
School


Road Way El. 139'
Crest of Dam El.126'
Present Water Level El.100'
High Water Level in canal 132.5'
Avg. Water Level in Canal - El.130' Top of Flash Boards
Bottom of Canal El.105'
PROFILE ℄ OF CANAL.
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000



NOTE "F.D." DESIGNATES FLOODED AREA.

GENERAL MAP SHOWING LOCATION OF PLANT AND FLOOD LINES.



①

THESIS

PROPOSED HYDRO-ELECTRIC POWER PLANT ON BIG SALMON RIVER IDAHO

G. D. Pettibone A. M. Newhouse H. W. Jones
Scale 1" = 400 Ft. May 1911

HYDRAULIC LAYOUT.

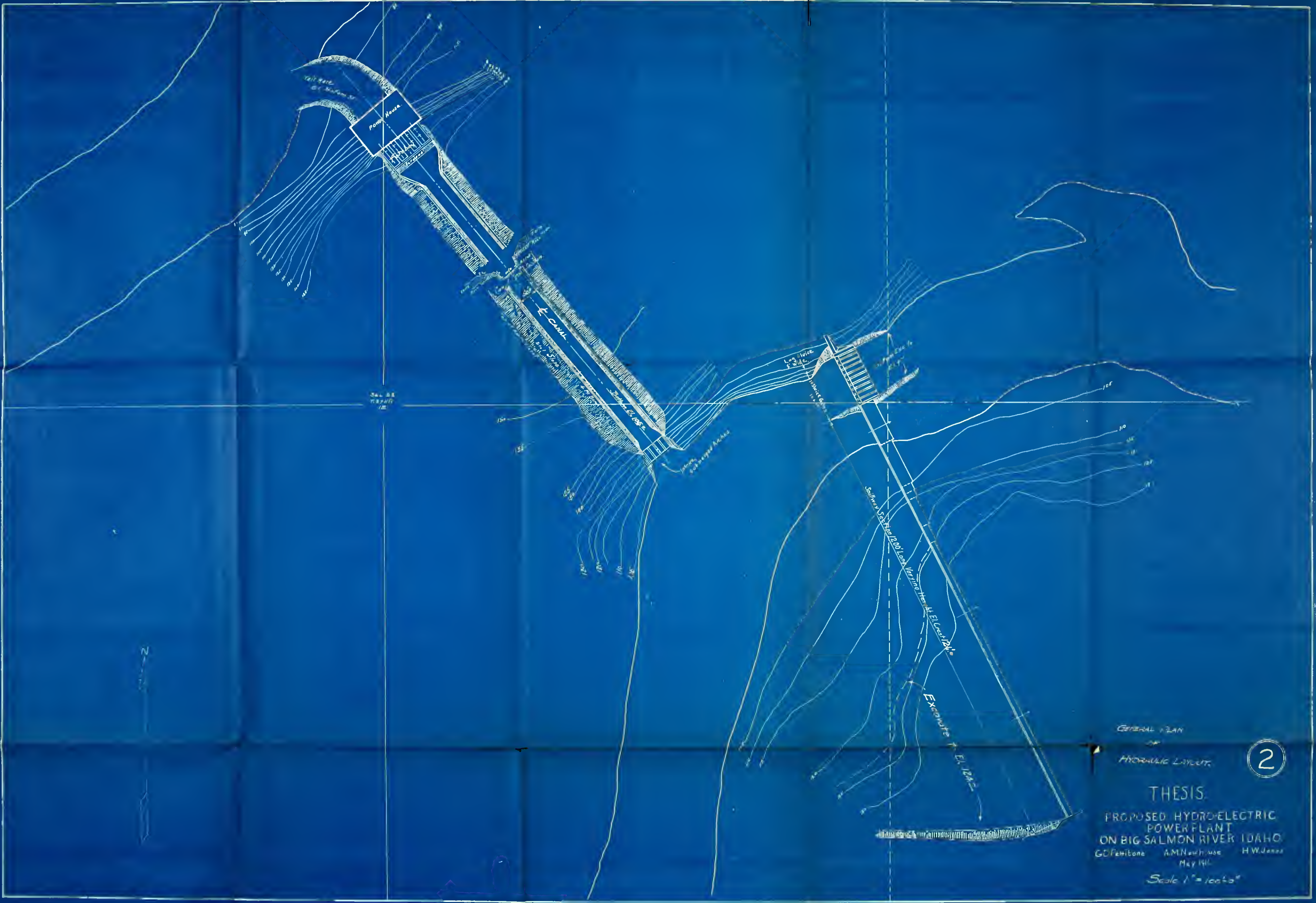
2

THESIS.

PROPOSED HYDRO-ELECTRIC POWER PLANT ON BIG SALMON RIVER IDAHO.

GDPettibone A.M.Newhouse H.W.Jones.
May 1911.

Scale 1" = 100'-0"



General Plan
of
Hydraulic Layout.

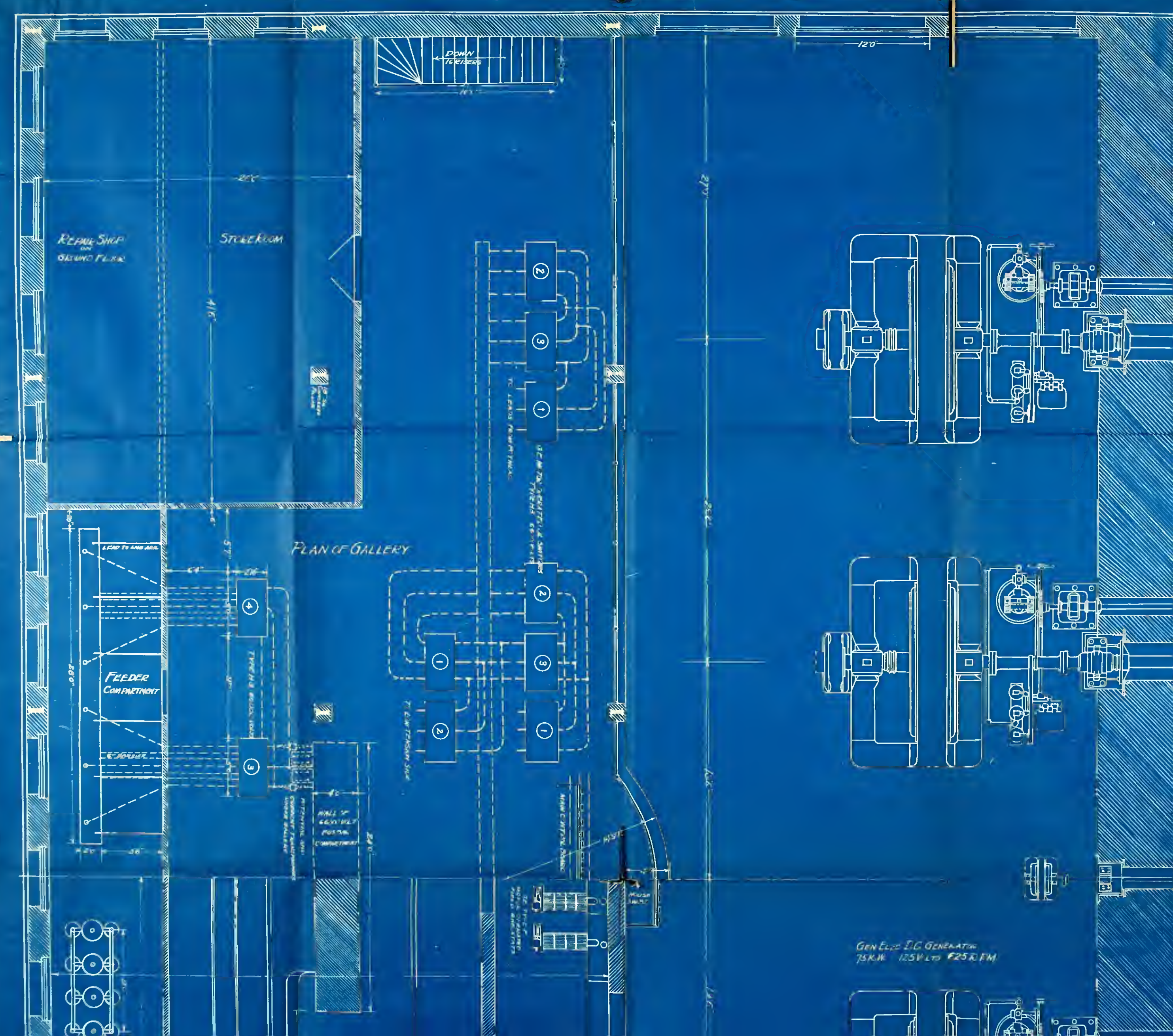
②

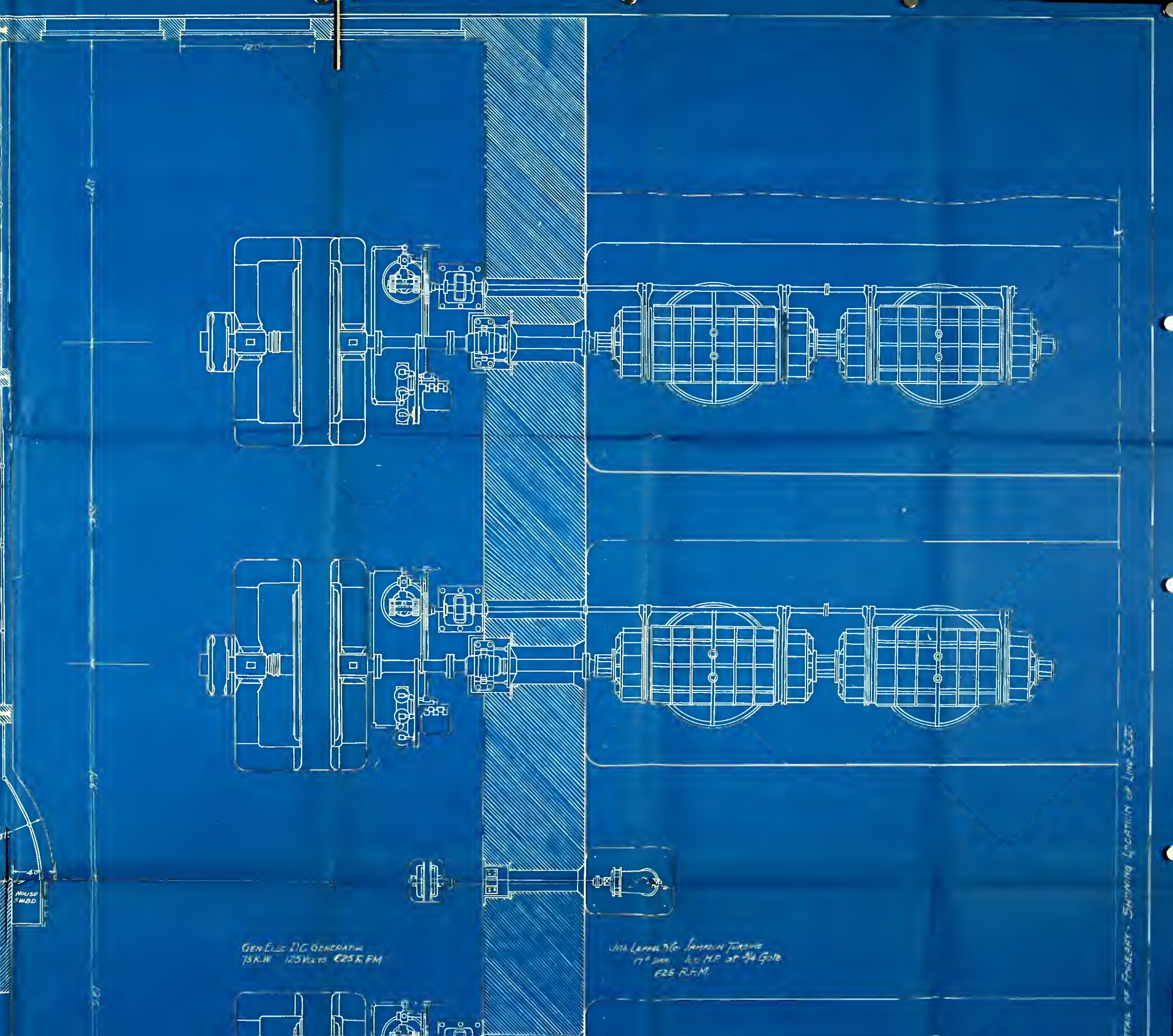
THESIS.

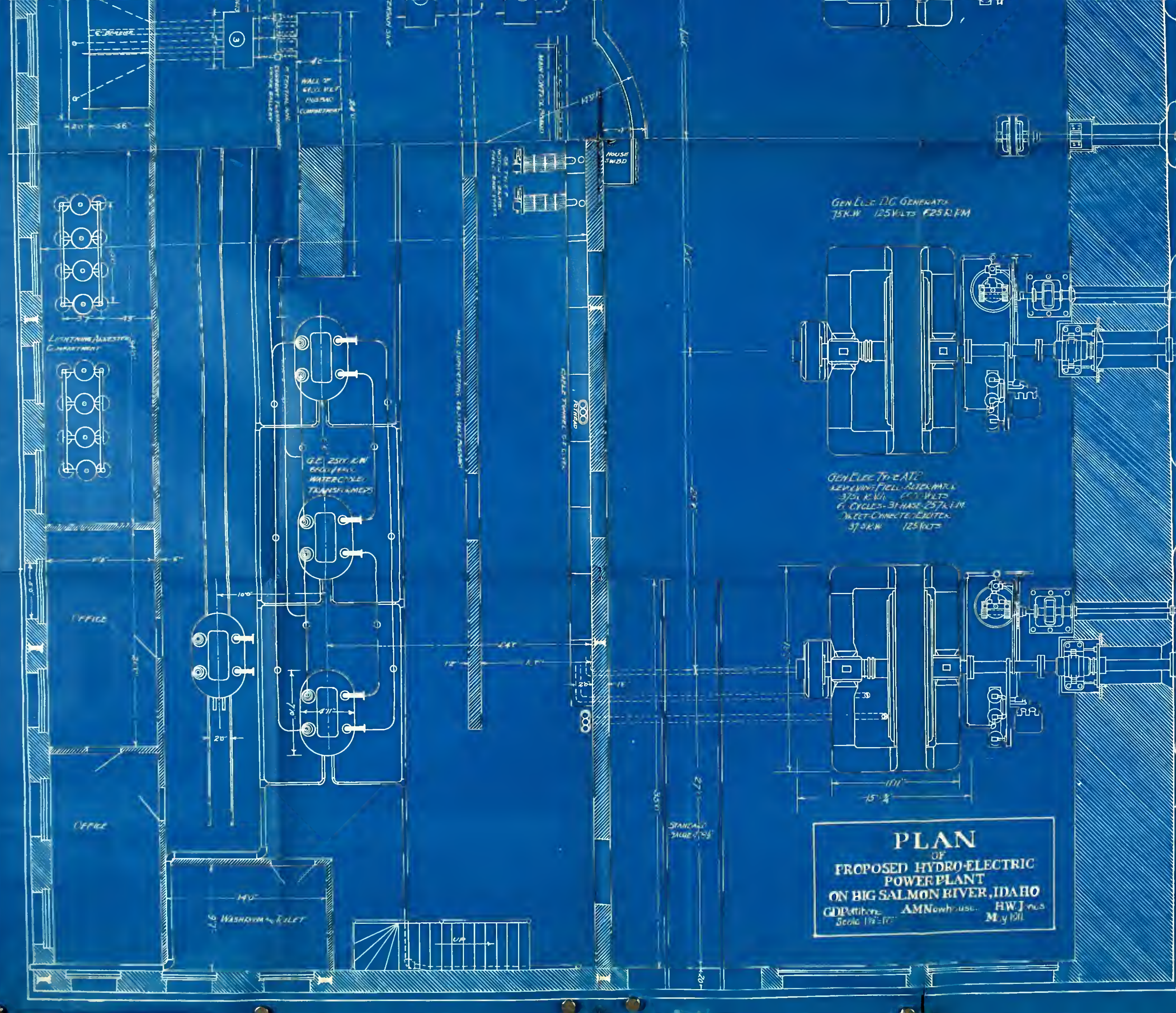
PROPOSED HYDRO-ELECTRIC POWERPLANT ON BIG SALMON RIVER IDAHO

G.D.Pettibone A.M.Newhouse H.W.Jones
May 1911

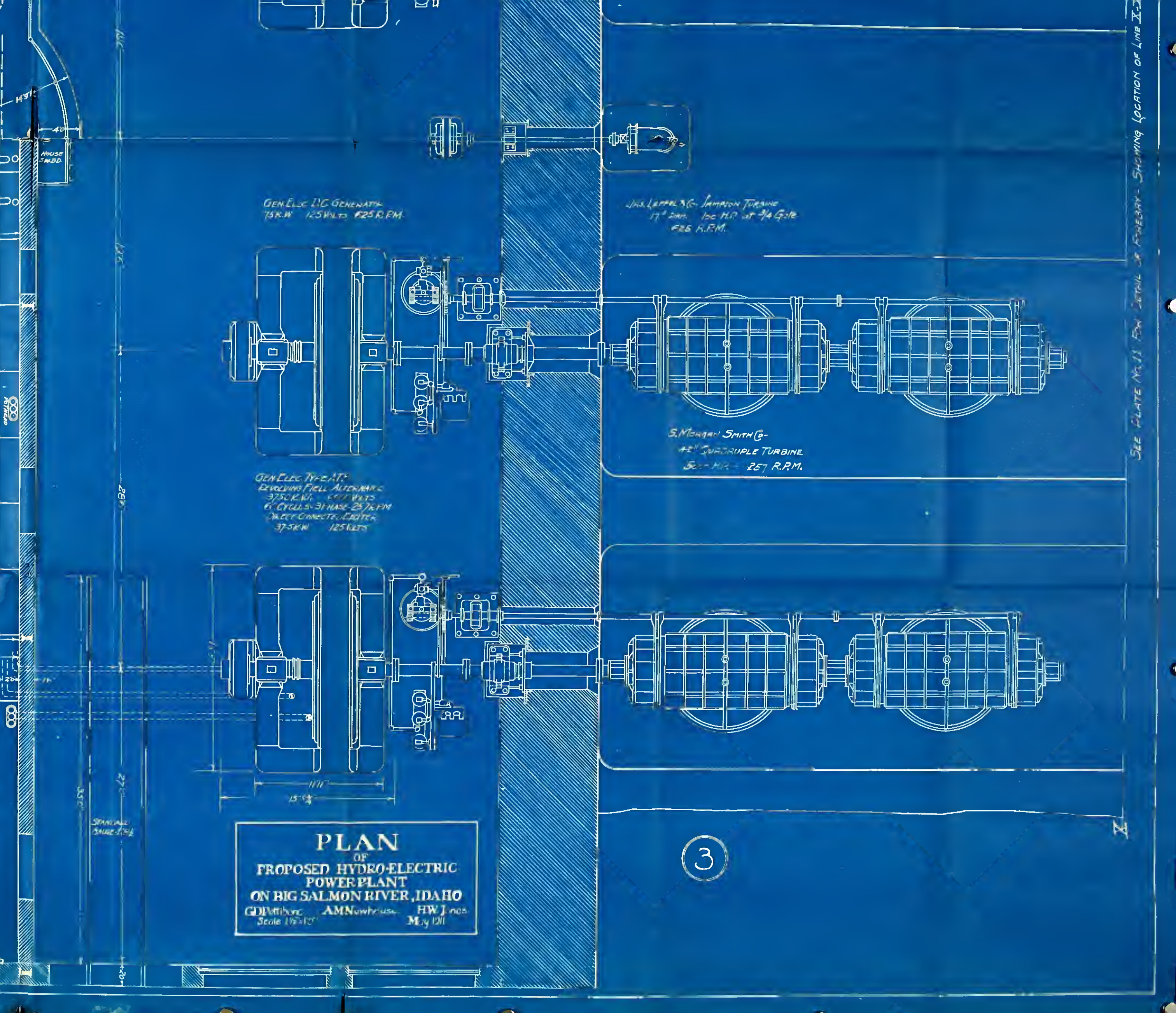
Scale 1" = 100'-0"


Down
16 Risers
12'0"
26'0"
41'6"
Repair Shop on Ground Floor
Store Room
Plan of Gallery
Lead to line rail
Feeder Compartment
6" Marble
28'0"
Type H.B. Oil Switches
Wall of 6600 Volt Bus Compartment
24'0"
Main Control Board
House Shaft
Gen Elec D.C. Generating
75 K.W. 125 Volts 625 R.P.M.


12'0"
4'0"
HOUSE SWBD.
GEN. ELEC. D.C. GENERATOR
75 K.W. 125 VOLTS 625 R.P.M.
JAS. LEFFEL & CO. SAMSON TURBINE
17" DIAM. 100 H.P. at 3/4 Gate
625 R.P.M.
TAIL OF FOREBAY - SHOWING LOCATION OF LINE X-X

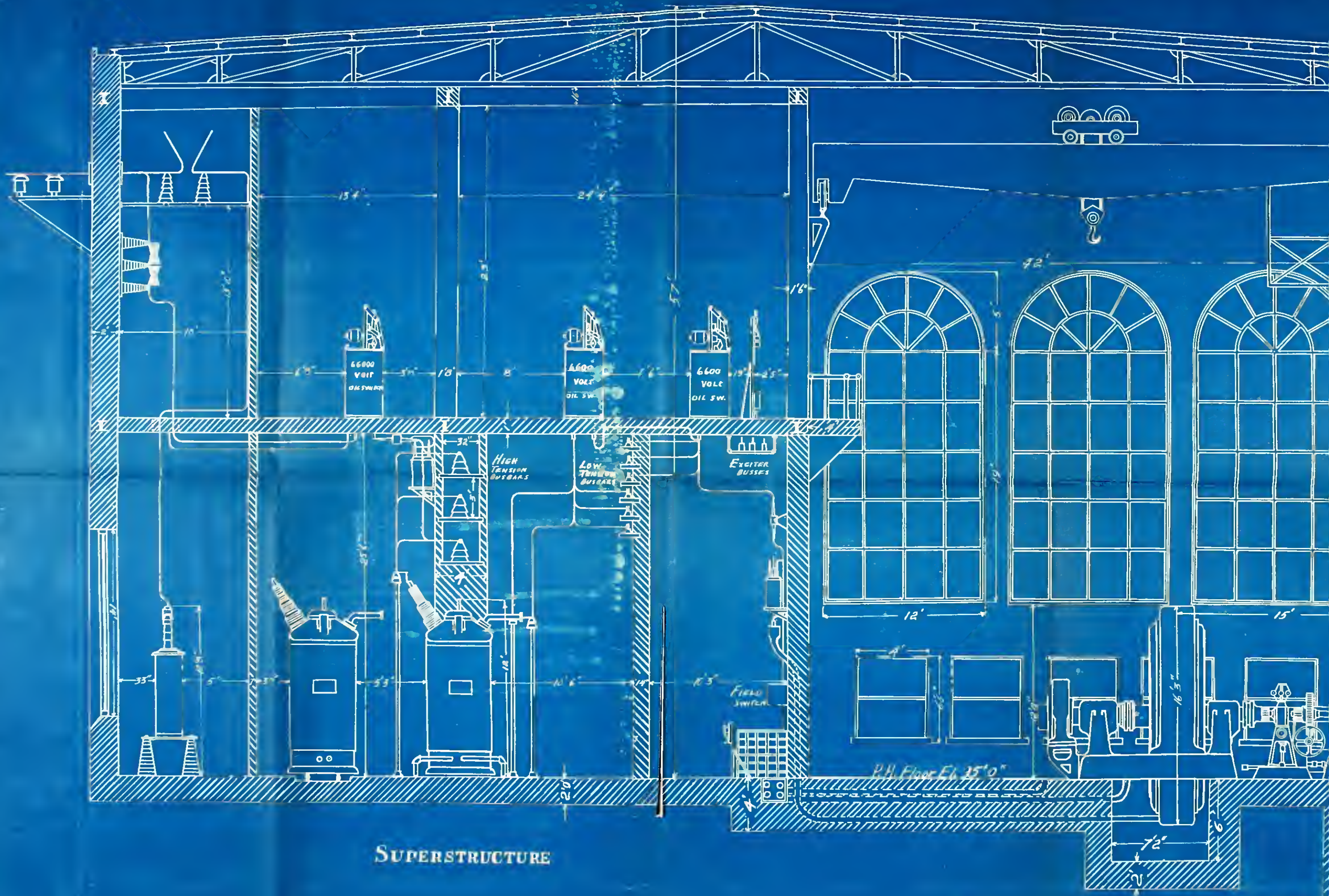


PLAN
OF
PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER, IDAHO
G.D.Pettibone AMNewhouse HW.Jones
Scale 1/8"=1'0" May 1911


House Swbd.
4'0"
Gen. Elec. D.C. Generator
75 K.W. 125 Volts 625 R.P.M.
Jas. Leffel & Co. Samson Turbine
17" Diam. 100 H.P. at 3/4 Gate
626 R.P.M.
Gen. Elec. Type ATB
Revolving Field Alternator
3750 K.V.A. 6600 Volts
60 Cycles - 3 Phase - 257 R.P.M.
Direct Connected Exciter
37.5 K.W. 125 Volts
S. Morgan Smith Co.
42" Quadruple Turbine
5000 H.P. - 257 R.P.M.
11'11"
15'5¾"
③
X
See Plate No. 11 For Detail of Forebay - Showing Location of Line X-X

PLAN
OF
PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER, IDAHO

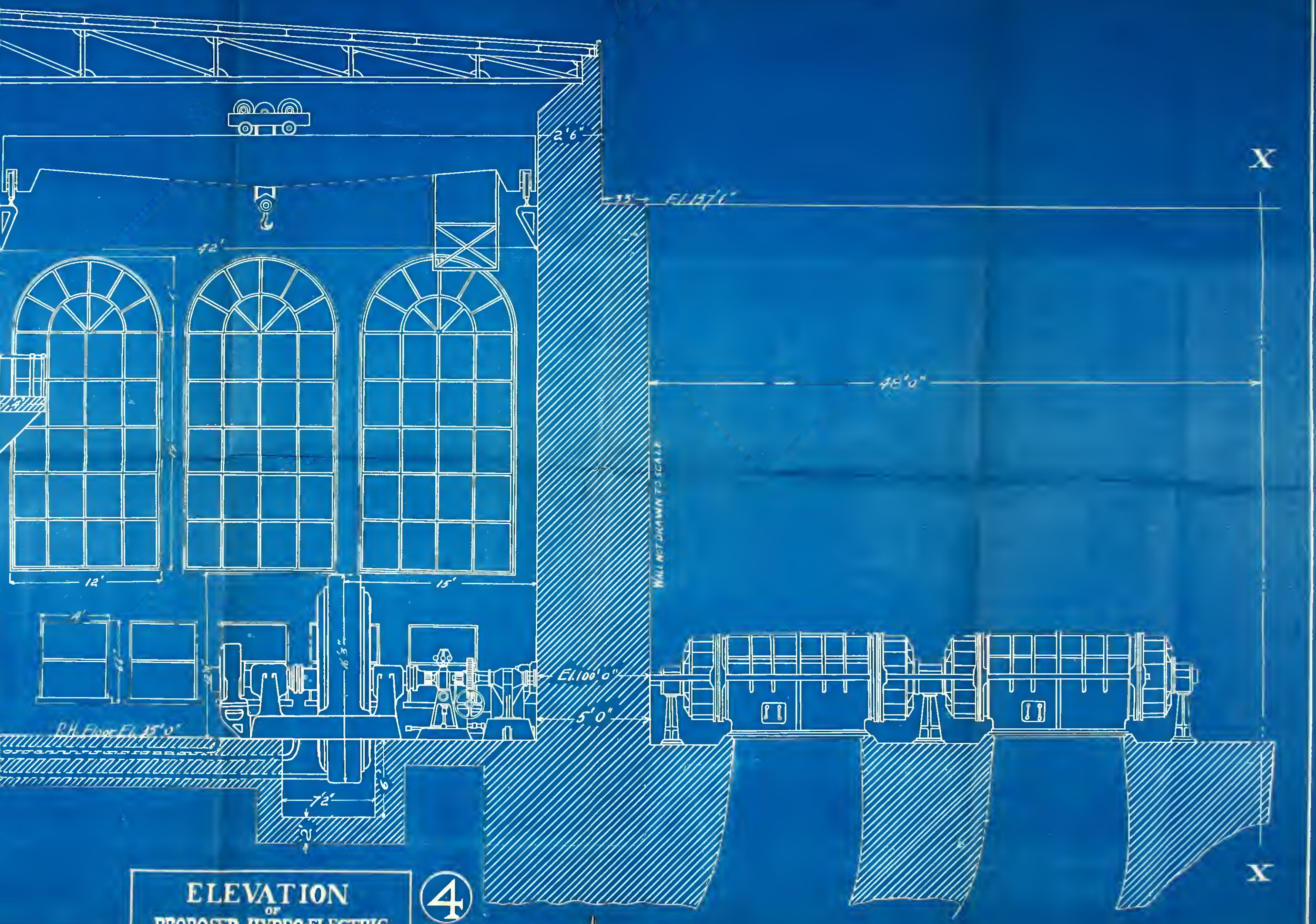
G.D. Pettibone A.M. Newhouse H.W. Jones
Scale 1/8"=1'0" May 1911



ELEVATION
OF
PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER, IDAHO

G.D. Pettibone A.M. Newhouse H.W. Jones
Scale 1/4" = 1'0" May 1911

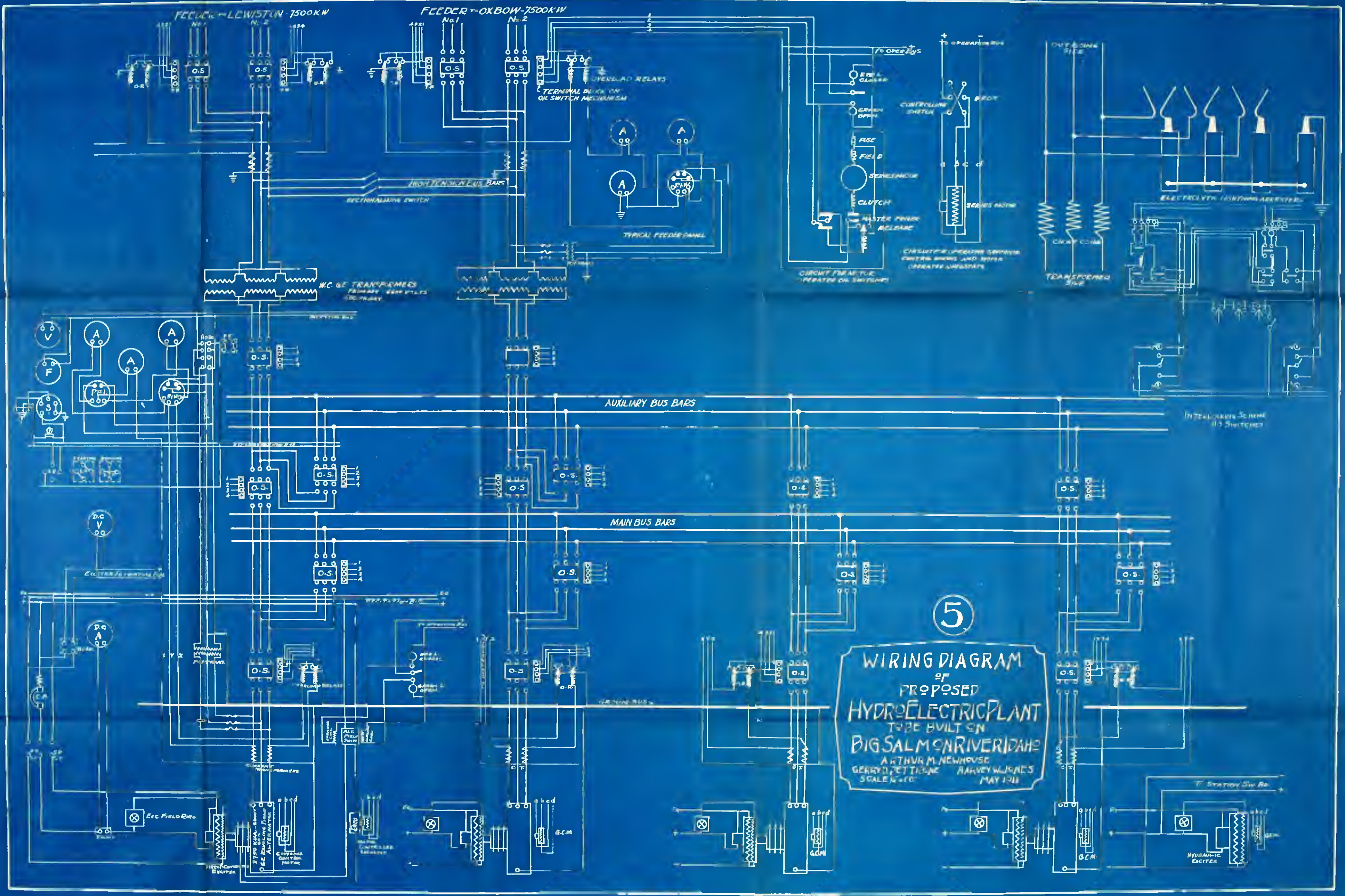
④



ELEVATION
OF
PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER, IDAHO

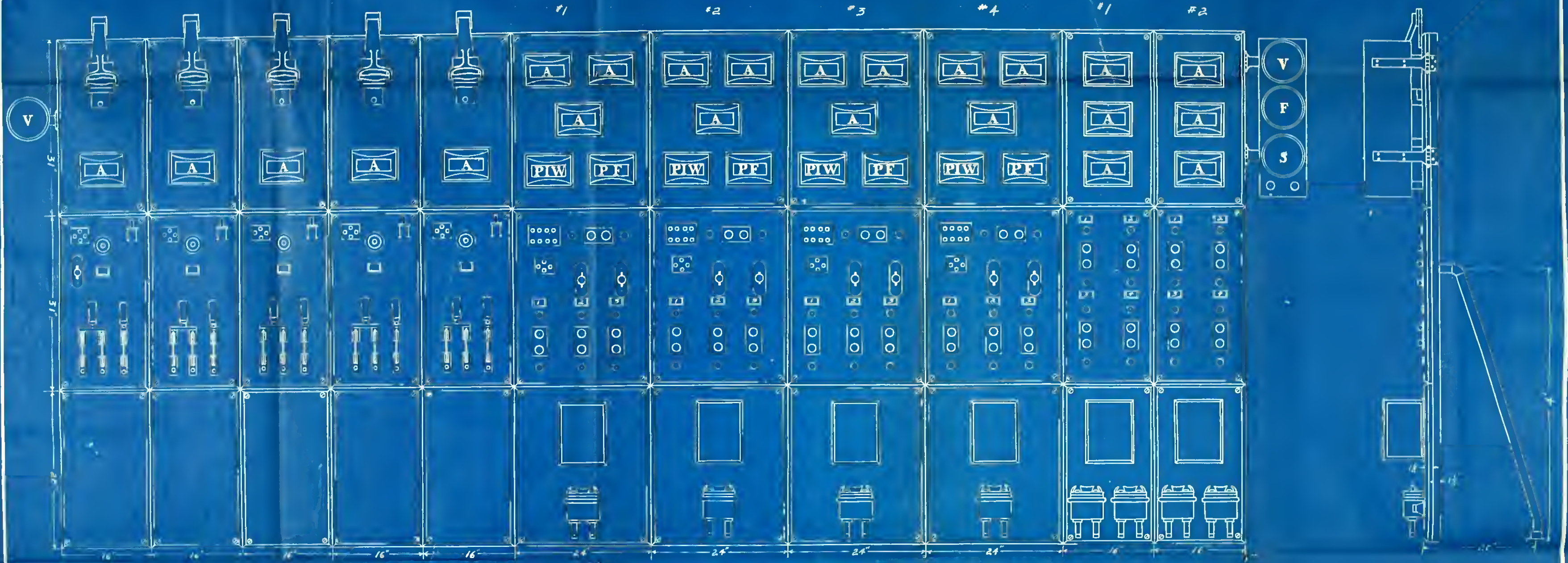
G D Pettibone A.M. Newhouse H.W. Jones
Scale 1/8"=1'0" May 1911

④



WIRING DIAGRAM
of
PROPOSED
HYDRO ELECTRIC PLANT
TO BE BUILT ON
BIG SALMON RIVER IDAHO

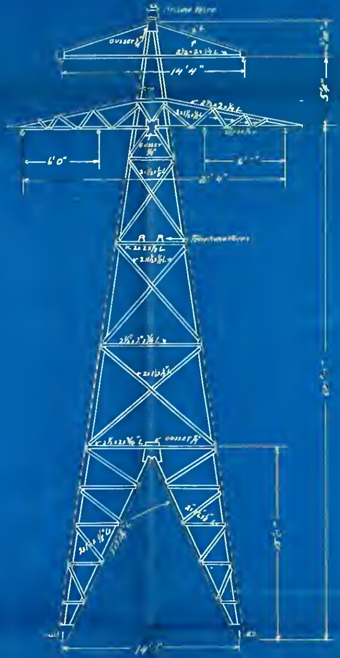
ARTHUR M. NEWHOUSE
GERRY D. PETTIBONE HARVEY W. JONES
SCALE [illegible] MAY 1911



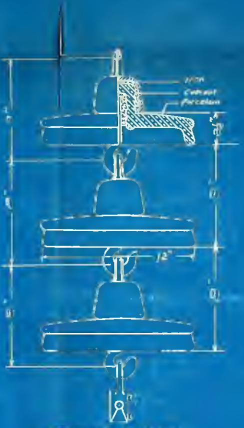
CONTROL BOARD
FOR
PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER IDAHO

G.D. Pettibone A.M. Newhouse H.W. Jones
Scale ½" = 1' May [illegible]

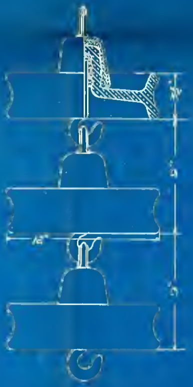
⑥



Typical Transmission Tower
Scale ⅛" = 1'



R. Thomas & Sons Co. No. 1061
Suspension Type Insulator
Rain Test per unit 53000 Volts
Dry Test per unit 75000 Volts
Weight per unit 12.25 lbs.
Scale 3" = 1'



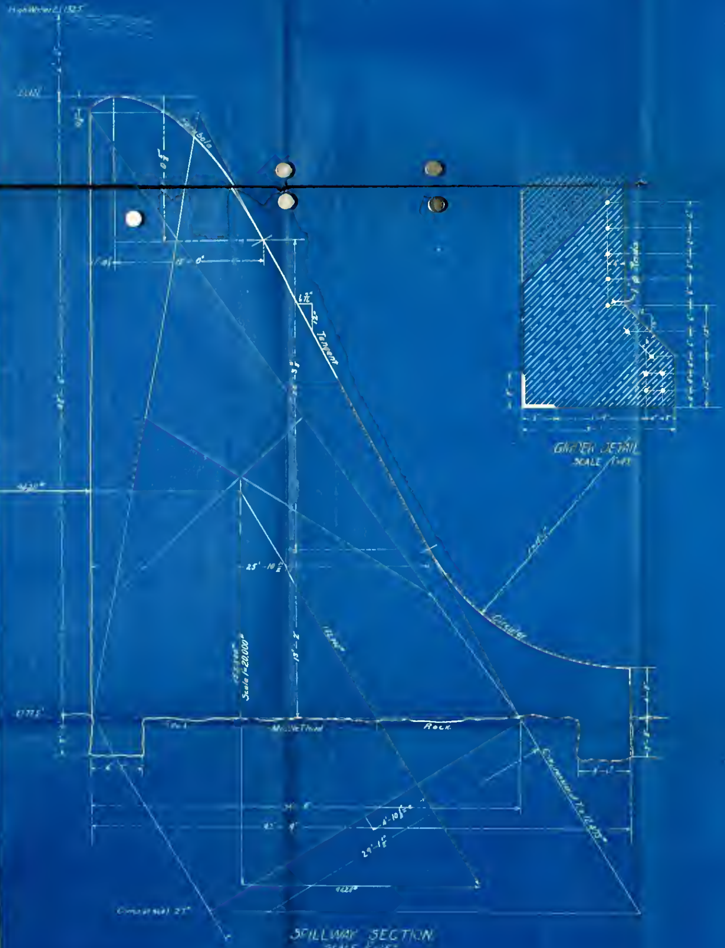
No. 1062
To be used as strain insulator
for dead ending and for bends
Rain Test per unit 53000 Volts
Dry Test per unit 82000 Volts
Weight per unit 22.5 lbs.
Scale 3" = 1'

TRANSMISSION TOWER

⑦

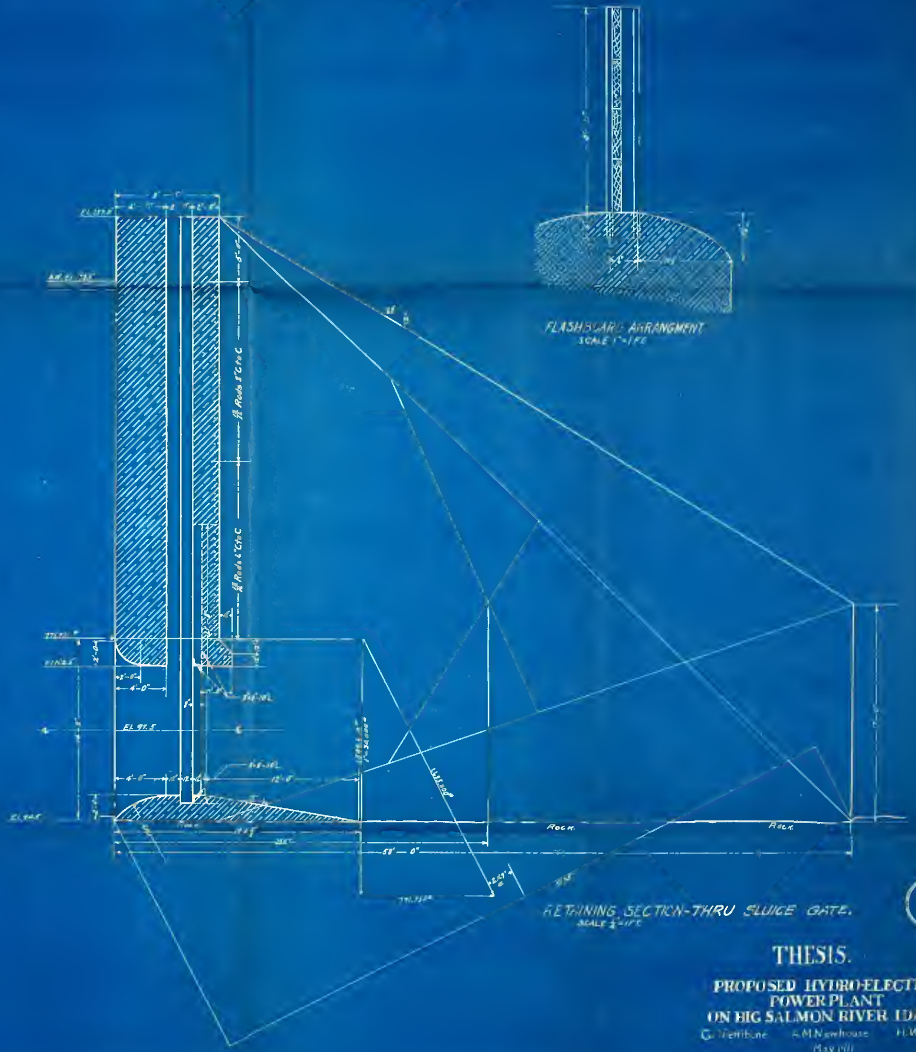
PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER IDAHO

A.M. Newmark G.L. Pettibone Harvey Jones
Scale as ind. May 1911.



SPILLWAY SECTION
SCALE 1/8"=1 FT.

GIRDER DETAIL
SCALE 1"=1 FT.



FLASHBOARD ARRANGMENT
SCALE 1"=1 FT.

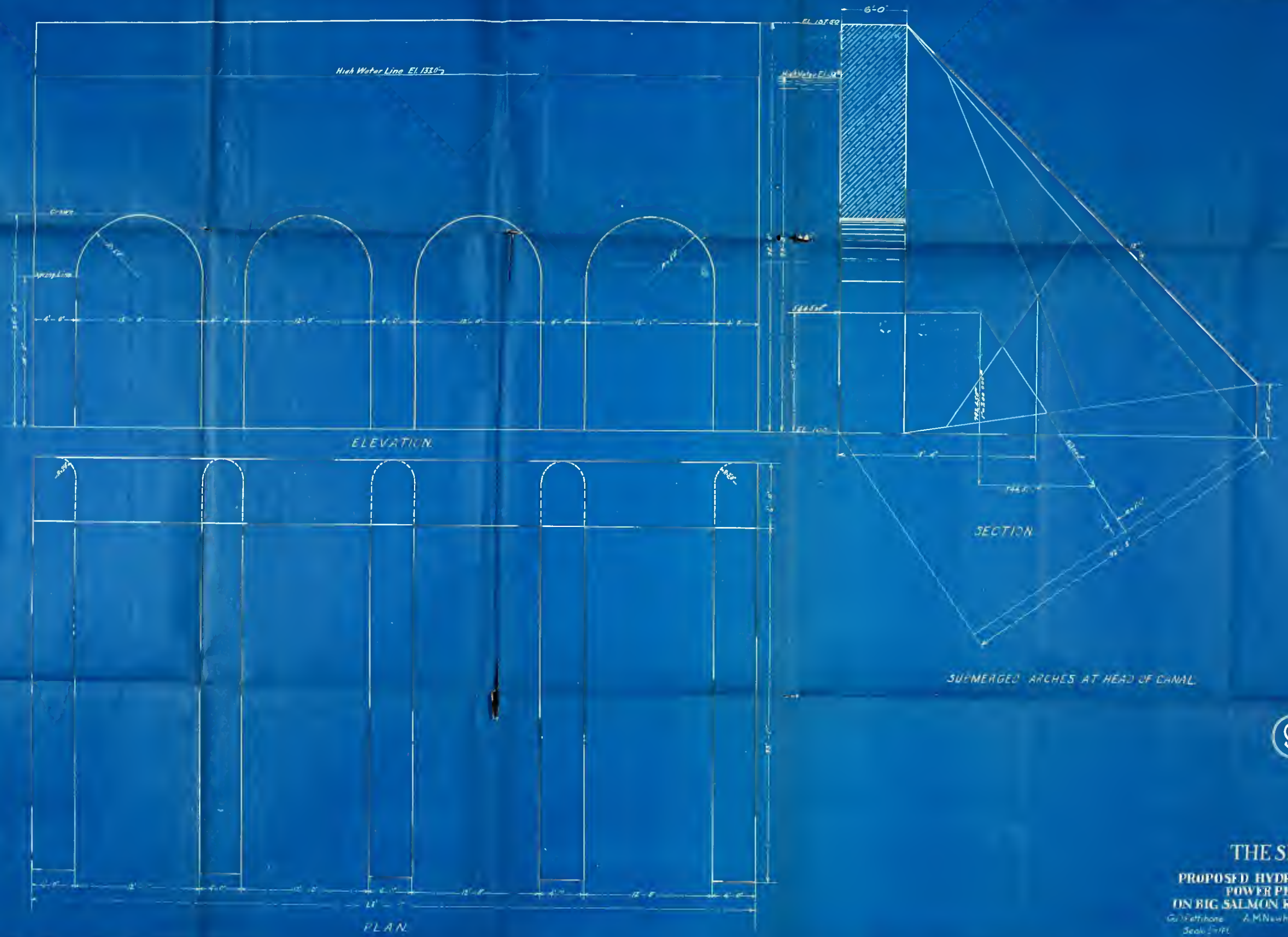
RETAINING SECTION-THRU SLUICE GATE.
SCALE ¼"=1 FT.

⑧

THESIS.

**PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER IDAHO**

G. Pettibone A.M. Newhouse H.W. Jones
May 1911



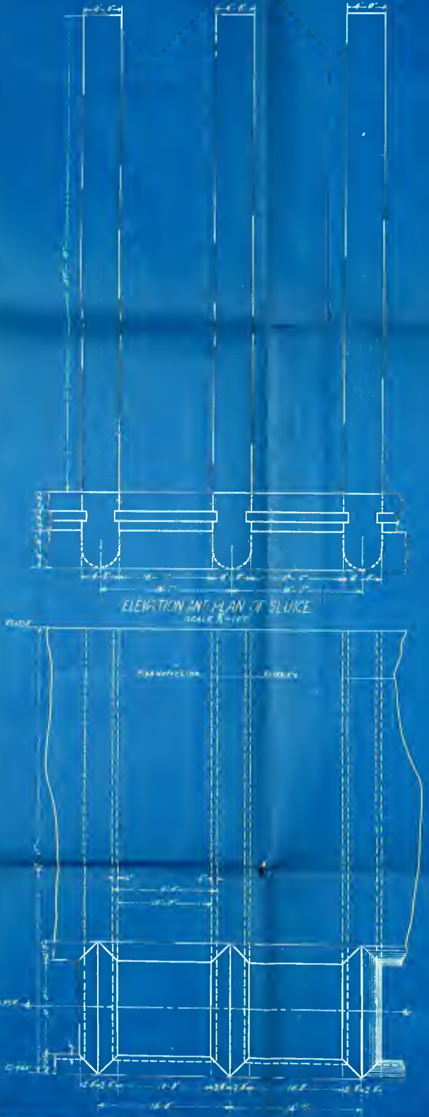
SUBMERGED ARCHES AT HEAD OF CANAL

⑨

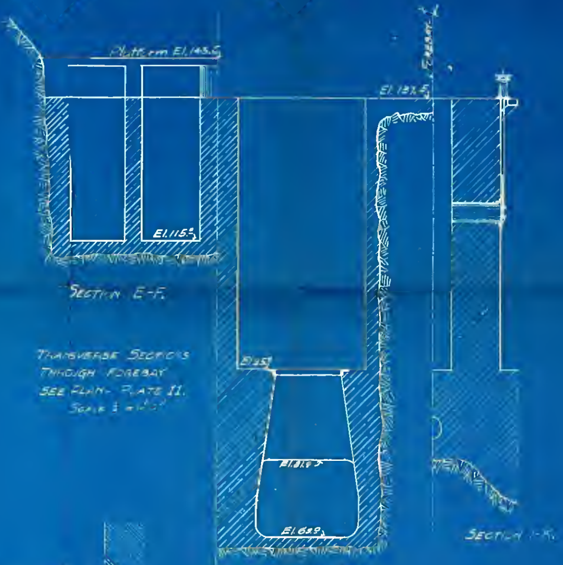
THESIS.

PROPOSED HYDRO-ELECTRIC POWER PLANT ON BIG SALMON RIVER IDAHO

G.J. Pettibone   A.M. Newhouse   H.W. Jones
Scale [illegible]   May [illegible]



ELEVATION AND PLAN OF SLUICE
SCALE [illegible]

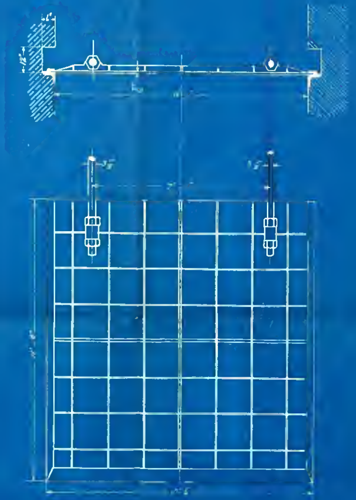


SECTION E-F.

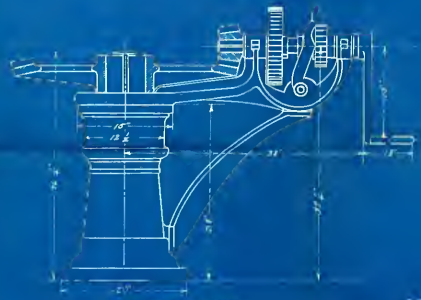
SECTION G-H.

SECTION I-K.

TRANSVERSE SECTIONS
THROUGH FOREBAY
SEE PLAN - PLATE II.
SCALE [illegible]



SLUICE-GATE AND GUIDES
SCALE [illegible]



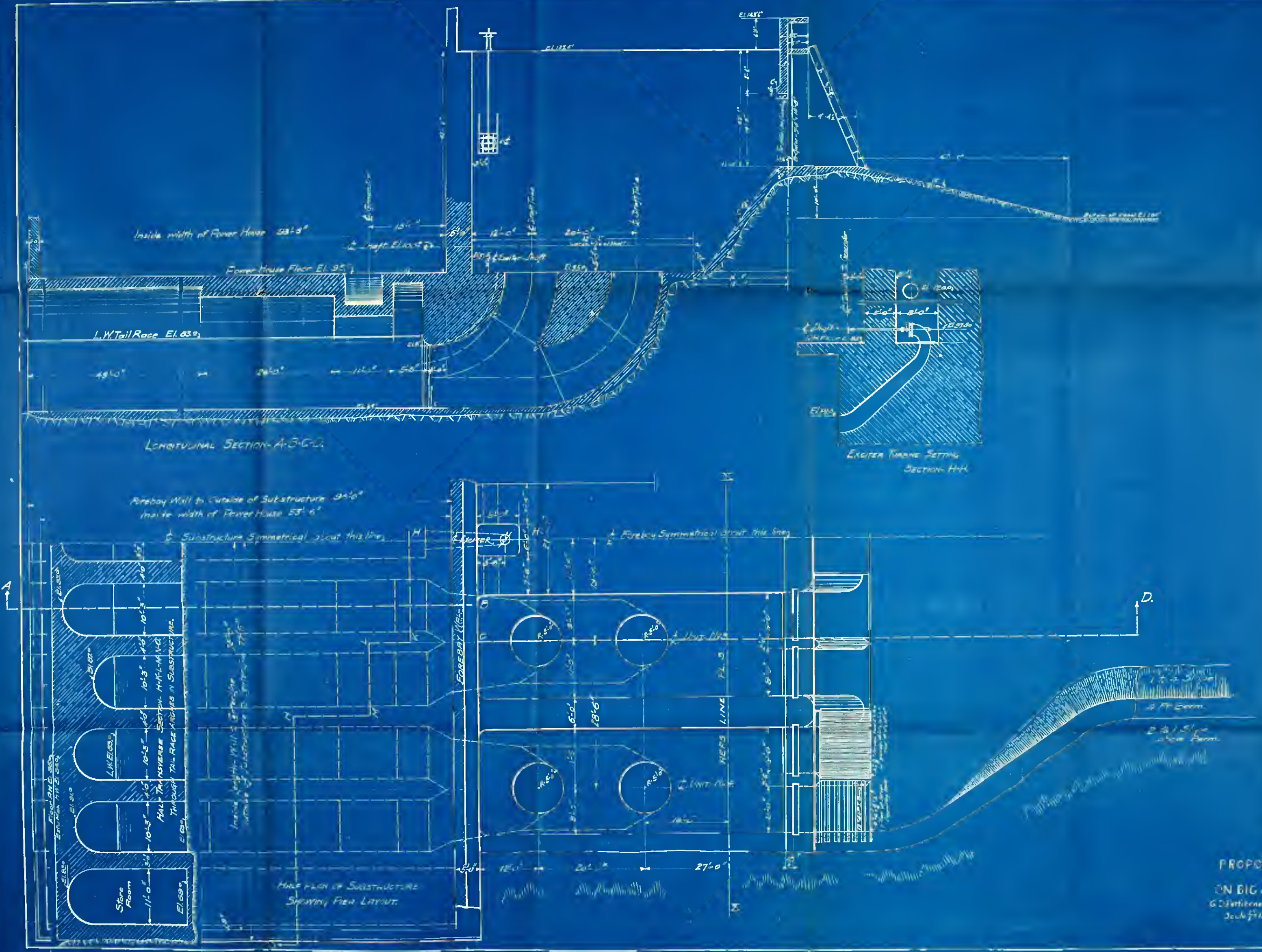
OPERATING STAND
SCALE 1½"=1FT

THESIS

⑩

PROPOSED HYDRO-ELECTRIC
POWER PLANT
ON BIG SALMON RIVER IDAHO
G.Orenibone A.M.Newhouse H.W.Jones
May 1911

1


El. 143.5'
El. 137.5'
Inside width of Power House 53'-6"
Power House Floor El. 95.7
L.W. Tail Race El. 63.9
49'-0"
26'-0"
11'-2"
5'-6"
12'-0"
20'-0"
6'-0"
15'-0"
Longitudinal Section A-B-C-D.
Exciter Turbine Setting Section H-H.
El. 120.0
El. 97.5
6'-0"
8'-0"
Bottom of Canal El. 118'
40'-0"
Forebay Wall to Outside of Substructure 94'-6"
Inside width of Power House 53'-6"
℄ Substructure Symmetrical about this line.
℄ Forebay Symmetrical about this line.
Exciter
Forebay Wall
R 5'-0"
℄ Unit No. 1
℄ Unit No. 2
18'-6"
6'-0"
27'-0"
Half Transverse Section H-K-L-M-N-O Through Tail Race Arches in Substructure.
Store Room
10'-3"
4'-0"
11'-0"
El. 63.9
Half Plan of Substructure Showing Floor Layout.
1 ½ : 1 Slope
4 Ft. Berm
2 ½ : 1 Slope
A
D.

11

THESIS.

PROPOSED HYDRO-ELECTRIC POWER PLANT ON BIG SALMON RIVER IDAHO

G. D. Fettibone A. M. Newhouse H. W. Jones

Scale ⅛" = 1 ft. May 1911